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RADIATION-EMITTING SEMICONDUCTOR COMPONENT

The invention relates to a radiation-emitting semiconductor component in accordance with the preamble of patent claim 1.

It relates in particular to a radiation-emitting semiconductor component having a layer structure which includes a photon-emitting active layer, an n-doped cladding layer and a p-doped cladding layer, and n-contact connected to the n-doped cladding layer and a mirror layer connected to the p-doped cladding layer.

This patent application claims the priority of German Patent Application No. 102 44 200.2, the content of disclosure of which is hereby incorporated by reference.

Radiation-emitting semiconductor components, such as for example InGaN-based top-down mounted luminescence diodes or thin-film luminescence diodes require highly reflective mirror materials which reflect radiation emitted from the active zone toward the component rear side back toward the front side or toward the component flanks.

In the case of top-down mounted luminescence diodes, the radiation-generating epitaxial layer sequence faces toward the mounting side, i.e. the component radiates through the growth substrate if still present. In the case of thin-film luminescence diodes, the growth substrate used for the epitaxial growth of the radiation-generating epitaxial layer sequence is at least partially removed and the epitaxial layer sequence is located on a carrier substrate applied subsequently.

Furthermore, for luminescence diodes based on nitride III-V compound semiconductor material, in particular based on GaN, such as AlGaN, InGaN and InGaAlN, and also GaN itself, the mirror materials are to form an ohmic contact with the p-doped layer of the layer structure.

The problem in this context is that metals of good reflective properties in the blue spectral region, such as aluminum, do not form an ohmic contact on p-GaN or related materials, such as p-AlGaN, p-InGaN and p-InGaAlN. On the other hand, materials which form a good contact on p-GaN, such as for example platinum or palladium, have an adsorbing action in the blue spectral region and are therefore not suitable for use as mirror material. Only silver is both sufficiently reflective and suitable for the contact-connection of p-GaN, etc. However, the drawback in this case is that the mechanical stability of silver layers is insufficient for use in luminescence diodes.

The group of radiation-emitting components based on nitride III-V compound semiconductor material in the present case include in particular chips in which the epitaxially produced semiconductor layer, which typically includes a layer sequence composed of various individual layers, includes at least one individual layer which comprises a material from the nitride III-V compound semiconductor material system $In_xAl_yGa_{1-x-y}N$, with $0 \le x \le 1$, $0 \le y \le 1$ and $x + y \le 1$. The semiconductor layer may, for example, have a conventional pn junction, a double heterostructure, a single quantum well structure (SQW structure) or a multiple quantum well structure (MQW structure). Structures of this type are known to the person skilled in the art and are therefore not explained in more detail at this point.

The choice of mirror material is also difficult in the

case of short-wave thin-film luminescence diodes based on InGaAlP. Gold, which is often used as mirror material at present, limits the efficiency of these diodes, on account of its relatively low reflectivity. Silver, which is more suitable in terms of reflectivity, has not hitherto been used, on account of its poor bonding and on account of migration problems.

One approach aimed at eliminating these difficulties consists in using aluminum mirrors, in which the electrical terminal is formed by a platinum layer and the optical properties are provided by the aluminum. Alternatively, it is possible to deposit silver which is fixed to a side facing away from the wafer by further metals.

The present invention is based on the object of providing a radiation-emitting semiconductor component of the type described in the introduction having an improved mirror layer and thereby of increasing the efficiency and performance of these components.

This object is achieved by a radiation-emitting semiconductor component having the features of patent claim 1. Advantageous configurations and refinements are given in subclaims 2 to 13.

According to the invention, in a radiation-emitting semiconductor component of the generic type, the mirror layer is formed by an alloy of silver with one or more metals selected from the group consisting of Ru, Rh, Pd, Au, Os, Ir, Pt, Cu, Ti, Ta and Cr. The addition of these metals makes it possible to significantly improve the mechanical properties of silver layers without reducing the reflectivity of the layer compared to pure silver. At the same time, the diffusion of silver into the adjoining semiconductor layer is reduced.

In one preferred configuration of the radiation-

emitting semiconductor component according to the invention, the mirror layer is formed by an alloy of silver with one or more metals selected from the group consisting of Ru, Rh, Pd, Au, Os, Ir, Pt and one or more metals selected from the group consisting of Cu, Ti, Ta, Cr. Ternary alloys of this nature have both a high reflectivity in the desired short-wave spectral region and a sufficient mechanical stability.

It is considered particularly preferable for the mirror layer to be formed by an Ag-Pt-Cu alloy. This alloy combines a high reflectivity in the blue spectral region with a high mechanical and thermal stability.

It is advantageously provided in this context that the alloy of the silver layer, in addition to silver, comprises a total of 0.1% by weight to 15% by weight, preferably 1% by weight to 5% by weight, of the abovementioned metals.

In a preferred refinement of the radiation-emitting semiconductor component according to the invention, it is provided that the alloy of the mirror layer, in addition to silver, comprises 0.5 to 5% by weight of one or more metals selected from the group consisting of Ru, Rh, Pd, Au, Os, Ir, Pt and 0.5 to 5% by weight of one or more metals selected from the group consisting of Cu, Ti, Ta, Cr.

In this context, the alloy of the mirror layer of the radiation-emitting semiconductor component comprises in particular, in addition to silver, 1 to 3% by weight of platinum and 1 to 3% by weight of copper.

In an expedient refinement of the invention, the mirror layer forms an ohmic contact with the p-doped cladding layer, so that the mirror layer can simultaneously perform the function of a p-contact layer.

The configuration of the mirror layer according to the invention is particularly suitable for use in radiation-emitting semiconductor chips, in particular thin-film light-emitting diode chips, in which the radiation-generating layer structure is based on InGaAlN or InGaAlP. In particular, ohmic contacts can be produced using silver-containing alloys for InGaAlN-based luminescence diodes. Therefore, the mirror metallization can be produced directly above a light-generating layer.

A thin-film light-emitting diode chip is distinguished in particular by the following characteristic features:

- a reflective layer is applied to or formed on a first main surface, facing a carrier element, of a radiation-generating epitaxial layer sequence, the reflective layer reflecting at least some of the electromagnetic radiation generated in the epitaxial layer sequence back into the latter;
- the epitaxial layer sequence has a thickness in the range of 20 μm or below, in particular in the region of 10 μm; and
- the epitaxial layer sequence includes at least one semiconductor layer with at least one surface which has a mixed structure which ideally leads to an approximately ergodic distribution of the light in the epitaxial layer sequence, i.e. it has as far as possible ergodically stochastic scattering properties.

A basic principle of a thin-film light-emitting diode chip is described, for example, in I. Schnitzer et al., Appl. Phys. Lett. 63 (16), October 18, 1993, 2174-2176, the content of disclosure in this respect is hereby incorporated by reference.

A thin-film light-emitting diode chip is, to a close approximation, a Lambert radiator and is therefore

particularly suitable for use in a headlamp.

In the present context, the term "radiation-generating layer structure based on InGaAlP" means that a layer structure designated as such or part of a layer structure of this type preferably comprises $Al_nGa_mIn_{1-n-m}P$ where $0 \leq n \leq 1$, $0 \leq m \leq 1$ and $n + m \leq 1$. This material does not necessarily have to have a precise mathematical composition in accordance with the above formula. Rather, it may also include one or more dopants and additional constituents which leave the physical properties of the material substantially unchanged.

In the present context, the term "radiation-generating layer structure based on InGaAlN" means that a layer structure designated as such or part of a layer structure of this type preferably comprises $Al_nGa_mIn_{1-n-m}N$, where $0 \leq n \leq 1$, $0 \leq m \leq 1$ and $n+m \leq 1$. This material does not necessarily have to have a mathematical composition precisely in accordance with the above formula. Rather, it may include one or more dopants and additional constituents which leave the physical properties of the material substantially unchanged.

Further advantageous configurations, features and details of the invention will emerge from the dependent claims, the description of the exemplary embodiment and the drawing.

The invention is explained in more detail below on the basis of an exemplary embodiment in conjunction with the drawing, which illustrates in each case only the elements which are of relevance to gaining an understanding of the invention. In the drawing:

Figure 1 shows a diagrammatic sectional illustration of a radiation-emitting semiconductor

component in accordance with an exemplary embodiment of the invention.

Figure 1 shows a diagrammatic sectional illustration of an InGaN luminescence diode 10 which emits in the blue spectral region. The luminescence diode 10 includes a layer structure 12 comprising an n-doped cladding layer 14, a photon-emitting active layer 16 and a p-doped cladding layer 18.

An n-contact 22 is arranged on the n-doped cladding layer 14 for the purpose of supplying current. In the exemplary embodiment, the p-contact is formed by the p-contact layer 20, which simultaneously forms a highly reflective mirror layer which reflects the component of the radiation generated by the active layer 16 in the direction of the mirror layer.

In the exemplary embodiment, the mirror layer 20 consists of an AgPtCu alloy containing approximately 1.5% by weight of platinum and approximately 1.5% by weight of copper. This alloy on the one hand forms a good ohmic contact with the p-GaN cladding layer 18. Furthermore, the addition of platinum and copper to silver significantly improves the mechanical properties of the silver layer. The high reflectivity of the mirror layer in the blue spectral region is retained. Furthermore, there is scarcely any diffusion of silver atoms out of the AgPtCu layer 20 into the p-doped cladding layer 18, and as a result a highly reflective, stable p-contact layer is obtained.

A mirror layer of this type formed from an AgPtCu alloy is furthermore also suitable for use in InGaAlP thin-film luminescence diodes, where, as a highly reflective and thermally stable metal mirror, it contributes to increasing the efficiency of the LEDs.

Alternatively, the mirror layer may consist of an

AgPtRhCu alloy, an AgPtCuTi alloy or an AgPtRhCuTi alloy or another of the advantageous alloys listed in the general part of the description.

The features of the invention which are disclosed in the above description, in the drawing and in the claims may be pertinent to the realization of the invention both individually and in any desired combination.